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PERSPECTIVES OF TECHNICAL MATERIALS

PERSPEKTIVY TECHNICKÝCH MATERIÁLŮ

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Abstract

In this paper I intend to show the problems connected with the development of materials in the material engineering. The materials are traditionally devided in three basic groups: the metals, the ceramics and the polymers. This conventional classification has the origin in the type of interatomic bonds, which is determining the final properties of given materials.

Key words: composites, ceramics, polymers

The progressive group of materials is formed by composites, based on the connection of two or more materials leading to the unconventional final properties. The final properties depend on the properties of the individual components and on their volume participation, geometry and their interaction. To reach the very high level of such properties is conditioned by the research and development in the material characteristics and in the new material technologies.

From the ceramic materials, such as the Si_3N_4, SiC, partially stabilized ZrO_2, Al_2O_3, BN, etc., some of them may be taken as the base of the qualified increment of their fracture toughness. The partially stabilized ZrO_2 contains as the stabilizer of high temperature phase the additions of Y_2O_3 or, MgO, respectively. In the material then operates the stress induced phase transformation of tetragonal phase ZrO_2 to monoclinic and at the same time of the increment of the specific volume by roughly 4 per cent. This is resulting in the decrease of stress level at the crack tip and this way in the reduction of the brittleness. E. g. by the composite of type $Al_2O_3 + ZrO_2 + Y_2O_3$ the major increase of fracture toughness may be reached.

The most of the mentioned types of the ceramic materials have the perspective of broader application in the automotive industry and in the power engineering. E. g. the corundum ceramics [Al_2O_3] is excellently biocompatible and chemically resistant. From these reasons is this material used for implantation purposes in human medicine and at dental applications.

Quite important spectrum of properties is presented by the process of the rapid solidification. At the cooling of the metal melt by the cooling rate of 10^5 K/s, and higher, it is possible to obtain the new material variant. The base characteristic which could be reached by the process is the formation of broad regions of solid solutions, and possibly the very fine precipitation of homogenously distributed secondary phases in the basic matrix.

Also the formation of non-equilibrium crystal components in the microstructure is possible. At the highest cooling rates and at the suitable chemical composition of the material the amorphous state can be reached. The rapid solidification is suitable to the preparation of material in the form of very fine microscopic particles, cooled by the intensive gas flow. Very rapid cooling on the rotating cylinder is leading to the origin of thin amorphous bands.

The above mentioned products can in the majority of cases serve as the as-received material for the further treatment. The manufacture of the rapid solidified microcrystalline powders and the amorphous materials may present only the first stage of further processing. At the present time there is for the disposition the scale of chemical compositions of amorphous materials for various use. In case of the requirement on very high strength round the level 3000 – 4000 MPa, the very high hardness and at the same time the high ductility, the composition of such system is in agreement with the convention requirement of the mutual composition of the metallic and metalloid phase, based on the Fe and B content. At the required increase of the resistance against the corrosion and stress induced corrosion the materials were developed, based on the Fe, Cr, Ni, P and C at the metalloid content of round 25%. Also very known materials are based on the composition $Co_{60}Fe_9(Mo,Si,B)_{30}$. This amorphous variant has extremely low magnetostriction and the initial permeability.

The mechanical alloying (MA) is presenting the technology usually used for the formation of bonds between the metal and the ceramic powders. The mixture of those powders is exposed to the mutual contact in the ball mills, where the particles are destroyed and then mutually bonded. This process is composed from the deformation of particles, their fracturing, their welding also with the fragments of particles, and, possibly the introduction of powder Y_2O_3, if the chemical constitution is corresponding well to the original alloy. From such prepared mechanically alloyed (MA) powder we receive the green row material, which is further treated by the extrusion, hot rolling and heat treatment.

The increased level of the creep is the result of the presented dispersion hardening – e. g. by the Ni – supperalloys. Very high creep characteristics were obtained at the alloy MA6000E. Such characteristics are substantially higher than e. g. by the alloy IN 792.

Apart from the presented cases of mechanical alloying by the Ni-alloys the attention is now paid to the MA of Al-alloys (Al-4Mg-1.3Li-1.1C), which find the suitable application in the air-industry. It is possible to reach the 8% of lower specific weight at the 12% of increase of elasticity modulus. In comparison with the conventional Al-alloys it is possible to decrease the weight of air-plane structure by roughly up to 15%.

In recent time the attention is paid also to intermetallic compounds, which represent the conglomerate of properties of metallic and ceramic materials. Today are such materials used in the structures working at high stresses and at very high temperatures. The composition of such material is the multiphase alloy, where the hardening compound is the intermetallic alloy. From these reasons the attention is paid to the development of new materials, constituted on the basis of intermetallic compounds, which retain very high strength at the very high temperatures. The only the problem is low ductility of such materials. The research how to overcome such problems is open. The most interesting results were obtained at the alloys Ni_3Al, Ti_3Al, TiAl, etc.

The research on composite materials brings the list of possibilities for the technical application of these materials. We can present some of the most actual examples. The composite, hardened both by the particles and the fibres (MMCs) based on the hardening of Al by the particles SiC is leading to the increased strength level and the rigidity of components, when compared to the non-hardened material. In case of composites based on the Al or Al-alloy matrix are arising the problems of the contact of liquid metal with the non-metallic particles. The liquid metal has not enough wetting power which is leading to the not sufficient infiltration and to the degradation of properties of the hardening materials (mainly the graphite materials). So the broad practical use of the MMCs materials depends on the solution of such problems.

At the present time there is marked effort to research and development of the carbon materials, either on the basis of fibres or the graphite tubes. The graphite crystals are characterized by both the high strength and the high modulus of elasticity. Those parameters are obtained in the direction of basal plane. The high parameters are in agreement with the double bonds between the carbon atoms. When the fibres are composed of the polyacrylonitril (PAN), we can reach the modulus level 230 GPa and the strength 6 – 7 GPa. At the high modulus variant of the carbon fibres the obtained strength level is 3.5 GPa (3500 MPa).

Extraordinary attention may be paid to the function – gradient – materials (FGM), which also contribute to the material engineering properties. As an example may serve the covering of steel surface by the ceramic material, which provides such material by the gradient behaviour and by very good condition of the bonding of such different materials.

The nanocrystallic materials (NCM) are the single-phase of multiphase polycrystallic materials of the particle size of the order of maximum hundred nanometers. NCM have the atomic structure different from the two basic structures we know (crystal state and glass-amorphous state). The NCM have the structure which we may observe as the random atomic ordering. NCM have the extreme high grain boundary density, and the 30 - 50% of the atoms are within the grain boundaries.

We may turn to the analysis of the progressive material characteristics of steels and the selected conventional technical metallic materials. It is also necessary to follow the direction of development of such materials and notice the improved level of strength and toughness properties. The modern concepts oriented on the increased level of properties are not only based on the modification of structure-mechanics characteristics e.g. by alloying or heat treatment, but also on the controlled governing of the metallurgical properties. At the same time are followed the mutual relations between the metallurgical parameters and the final properties. We have to follow also the base requirements in the sphere of welding, mainly by defining the technical and the technological problems of the individual processes.

One of principal modification of the properties of structural steels of higher yield strength (HSLA steels) is the decreasing of the carbon equivalent at the retaining or even increasing the strength and toughness. The aim of such approach is to reach the very fine microstructure with low grain size and the stability of such microstructure at the all hardening mechanisms in the steel matrix. This is resulting in the high toughness, high formability and in good weldability even at the severe conditions.

The interesting results are obtained at the development of the multiphase steels using the TRIP phenomenon. Sometimes it is marked as the new generation of low alloy steels with the increase strength properties. This type of steels is attaining the required properties by deforming the retained austenite which is present in the microstructure. Especially, the most marked increase of properties is observed, when the retained austenite is transformed by the deformation induction into the martensite. The presence of retained austenite is observed as the leading parameter of the TRIP steel.

Structural low alloy high strength steels applied in the power and chemical engineering are streaming not only to the increased mechanical properties but also to the higher requirements on the superpurity. Mainly it concerns the steels used at the higher temperatures and under long lasting loading.

The increased effort to produce the very clean steels is remarkable also in the sphere of the stainless steel production. By this way it is possible to attain the increased resistance against the segregation cracking in heat affected zone of the steels. For example, the martensitic high chromium steels are now produced with the very low carbon and nitrogen contents, which is increasing the resistence against the hydrogen embrittlement and the resistance against the corrosion. The superferrite and the austenitic steels of very low carbon and very low sulphur content are characterized by higher resistance against the intergranular corrosion, namely at the weld joints. In the connection with the resistance against the general or local types of corrosion the attention is paid to the attainment of optimum of the mechanical and the technological properties. As an example we may present the results of the martensitic or the martensitic-austenitic steels with the very low carbon and sulphur content, where the controlled steelmaking, casting, forming and heat treatment is resulting in excellent strength, toughness, weldability and the corrosion resistance in the moderate corrosive environments.

We expect the new developments in the purely austenitic stainless steels, where the original 316L steel play the main role. As an example, the variant of the steel with the increased Cr content (about 20%) and Mo content (6%) is fulfilling the role of high corrosion resistant material for years. The steel is characterized by the increased resistance against the pitting and crevice corrosion. The nitrogen content is increased on the level 0.2 % and together with the increased Cu level (up to 1.5%) they both increase the corrosion resistance of the steel mainly in the environments of aggressive acids.

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